Final Year Project I

Dissertation

NEW CELLULOSIC-BASED ACOUSTIC WALL BOARD MATERIAL FROM PAPER WASTE

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CERTIFICATION OF APPROVAL

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Approved:

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TRONOH, PERAK

SEPTEMBER 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

LUQMAN HAKIM BIN RAZALI

Abstract

Paper waste is a common pollution that encounter by the world nowadays. The paper industry ranks 4th in contribution to greenhouse gas emissions, and contribute 9% of the manufacturing sector's carbon emissions. Facts show that typical business office will produce about 1.5 pounds of paper waste per employee each day. Increase in generation of the paper waste around the world, especially in developing countries, has created a need to develop new ways to use this waste to obtain value-oriented products. Due to unlimited amount of waste that being produced every day, recycling it would be a tremendous solution. Paper waste is a rich source of cellulose, which can be chemically modified to produce valuable products. With certain composite combination, the properties of a paper can be enhanced and flexible. The purpose of this proposal is to represent an introduction about the project and state the problem along with the objectives and methodology used to solve the problem. The first chapter makes brief introduction about the project. The report continues with the second chapter, which is literature review. Then it is followed by methodology. The objective of the research is to study the effect of the combination of fiber and pulp to produce a new cellulosic material. It also observes the strength of the material of different fiber's orientation. The study focuses on two points, which are: the properties of the new cellulosic material after combined with fiber and the best fiber's orientation to use as an acoustic wall. The new cellulosic material will undergoes certain test and the result will determine the advantage of fiber used in recycled paper. The characteristic of the fiber will be discuss more in second chapter.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Pulp and paper fiber resources are plant materials obtained from trees or agricultural crops. These resources encompass plant materials harvested directly from the land, plant material byproducts or residuals from other manufacturing processes such as wood chips from sawmills and fibers recovered from recycled paper or paperboard. Different plant fibers have different physical properties that influence their utility in pulping and papermaking. In developing countries, about 60% of cellulose fibers originate from nonwood raw materials such as bagasse (sugar cane fibers), cereal straw, bamboo, reeds, esparto grass, jute, flax, and sisal. This document addresses environmental issues in pulp and paper manufacturing with unit production capacities greater than 100 metric tons per day (tpd).

To convert fiber resources into value products, pulping is one of the methods that can be used widely. Pulping generally refers to various industrial processes used to convert raw plant materials or recycled paper into a fibrous raw material known as pulp, which is used primarily to make paper or paperboard products. Wood pulps are categorized by pulping process, with two major categories known as chemical and mechanical. Actually both types of processes typically use a combination of chemical and mechanical means to reduce wood into pulp. After several process, finally the paper is created and being used worldwide. Due to its important function, paper has become one of the top wastes that being produces every day.

Waste Generation vs. Country Size

Country	Waste (Kg/ person/year)	Area Square miles	Percentage %
Puerto Rico	812	3,435	24
United States	701	3,618,770	0.02
Canada	646	3,831,033	0.02
Norwich	512	125,182	0.4
Netherlands	484	15,770	3
Luxemburg	436	998	44
Germany	417	137,857	0.3
Switzerland	406	15,941	3
Japan	400	145,875	0.3
Austria	367	32,377	1
Belgium	358	11,783	3
Denmark	351	16,638	2

Figure 1.1: Paper waste that generate by countries around the world

The best solution for this problem is to recycle the waste into something useful. Recycling is defined as the act of extracting materials from the waste stream and reusing them. Today a wide variety of materials can be and are recycled. The most common recycled materials are paper, cardboard, plastics, aluminum, steel, and glass. It is no coincidence that these materials are the most recycled because they indeed are the most wasted. In this project, it will use the same concept as recycling but with a little modification to create a new, enhanced cellulosic material that can be used in variety of purposes.

1.2 Problem Statement

The amount of paper waste in learning institution is increasing from time to time due to the high usage in producing examination paper, paperworks and assignments. Apart from that, most of the student lack of awareness about the benefit of recycling paper. They probably know by recycling paper can reduce pollution and save the earth but it seems they did not see that values. Plus, the amount of recycling facilities and services in universities are less especially in UTP. Recycling bin is rarely found inside and the recycling services are not even established. To avoid the waste from becoming pollution, the paper is recycled and combines with fiber to produce a new multi-purpose material. Previous research shows that paper waste can be used to produce capacitors, synthetic calcium carbonate and many more. All of these new materials are useful to the industries and saves a lot of cost.

1.3 Objectives

The main objective of this project is to develop the methodology to produce cellulose based materials from paper waste with fiber reinforcement. Secondly it is to determine the mechanical properties of the new cellulosic material when natural fiber is used as reinforcement. For the reinforcement, it is to study the effect of fiber orientation toward the mechanical strength of the board. The orientation that will be applied in this research is isotropic and anisotropic's uniaxial and biaxial. This new material will be undergoes several testing in determining the effect after the combination. Last but not least, it is to assess the usefulness of the new cellulosic material as an interior acoustic wall board.

1.4 Scope of Study

The present research focused on evaluating several mechanical properties for the new cellulosic material. Properties such as strength and sound absorption will be tested and compared with the existing acoustic wall material which is the gypsum board. The research also covers the result of the fiber's orientation in pulping process. Different orientation will gives different result in the material strength. The project final scope is to produce acoustic wall board material from the paper waste that can be installed in lecture hall or study room. It is important to determine the best method and orientation to be used in producing a quality and safe acoustic wall.

CHAPTER 2

LITERATURE REVIEW

2.1 Pulping

Understanding the utility and value of pulp and paper fiber resources begins with an understanding of how fiber resources are converted into products of value to society through modern pulping and papermaking processes. Pulping generally refers to various industrial processes used to convert raw plant materials or recycled paper into a fibrous raw material known as pulp, which is used primarily to make paper or paperboard products. Plant materials such as wood, straw, or bamboo generally contain cellulose fibers together with lignin, a natural organic substance binding the cells, fibers and vessels which constitute wood and the lignified elements of plants, as in straw.

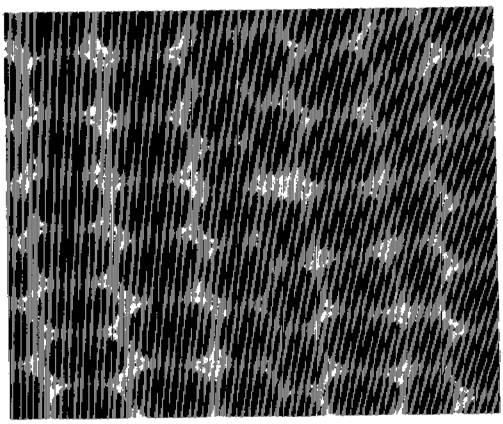


Figure 2.1: Lignin formation

Although pulping and papermaking are ancient technologies, commercial pulping and papermaking processes have advanced significantly since the eighteenth century, toward more capital-intensive and increasingly large-scale automated production processes, with continued emphasis on improvement in product uniformity and quality as well as production efficiency. Modern society places considerable value on uniformity of quality and efficiency in production of pulp, paper, and paperboard products. At the present time, most pulp produced worldwide is wood.

Wood pulps are categorized by pulping process, with two major categories known as chemical and mechanical. Actually both types of processes typically use a combination of chemical and mechanical means to reduce wood into pulp. Chemical pulping relies mainly on chemical reactants and heat energy to soften and dissolve lignin in wood chips, followed by mechanical refining to separate the fibers. Mechanical pulping often involves some pretreatment of wood with steam heat and/or weak chemical solution, but relies primarily on mechanical equipment to reduce wood into fibrous material by abrasive refining or grinding.

Region	*Chemical woodpulp*[a]	*Mechanical wood pulp*[b]	*Recycled pulp*[c]	*Nonwood pulp*[d]	*Totals*
Europe[e]	28.3	14.6	36.3	0.5	79.7
North America	66.1	16.3	35.7	0.2	118.3
Asia[f]	17.8	2.3	44.9	15.2	80.2
Australia and New Zealand	1.0	1.2	1.7	0.0	3.9
Latin America	9.9	0.4	6.9	1.1	18.3
Africa	1.7	0.3	1.3	0.7	4.0
World totals	124.8	35.1	126.9	17.7	304.4

Table 2.1: Global pulp production by category and region, 1999, in million metric tones

2.1.1 Mechanical Pulping

Mechanical pulping is a method of converting logs or wood chips into paper pulp for use in papermaking accomplished by mechanical grinding, as opposed to chemical pulping. The purpose of pulping is to reduce wood (or other fibrous raw material) to individual cellulose fibers. A non-fibrous constituent of wood, lignin, binds cellulose fibers together, and is primarily responsible for reducing paper quality and its permanence. Mechanical pulps are primarily used in newsprint, as well as papers used in telephone directories, catalogs, "pulp" magazines, and paper towels and tissues.

Traditional mechanical pulping involves forcing logs against a revolving stone, which grinds the logs into pulp by abrasive action. The stone is sprayed with water to remove fibers from the pulp stone, and to prevent fiber damage due to friction-generated heat.

The production of mechanical pulp or groundwood results in little removal of lignin content, and consequently produces paper that is not of as high a quality as other pulping methods that remove significant amounts of lignin. The advantages of mechanical pulping are its high pulp yield which is 100 pounds of wood can generate as much as 95 pounds of pulp, its low cost, and the paper it produces has several desirable printing qualities, such as high ink absorbency, compressibility, opacity, and bulk. Disadvantages, however, include low strength, low permanence, and a tendency to yellow with time. Paper made with mechanical pulps also contain shives, or incompletely ground fiber bundles.

Many pulps are bleached following pulping to increase brightness and whiteness, and to dissolve additional amounts of lignin. Mechanical pulps are bleached, but not to any great degree. Although some lignin is removed from groundwood pulps by bleaching, extensive bleaching can result in a decrease of pulp yield, defeating the primary advantage of the process. About 23% of the pulp used in the world is mechanical pulp. In most usages, however, groundwood pulp is combined with pulps produced chemically, to counteract the disadvantages of paper made with mechanical pulps.

The above method of producing groundwood pulp is the oldest pulping process. New mechanical pulping methods are reducing the disadvantages without compromising the advantages of mechanical pulping. Refiner mechanical pulping (RMP) sandwiches wood chips between two or three revolving disks. Heat due to friction softens the lignin and allows greater separation of the cellulose fibers, while contributing less fiber damage. RMP has greater strength than traditional groundwood, which reduces the need to supplement it with chemical pulps.

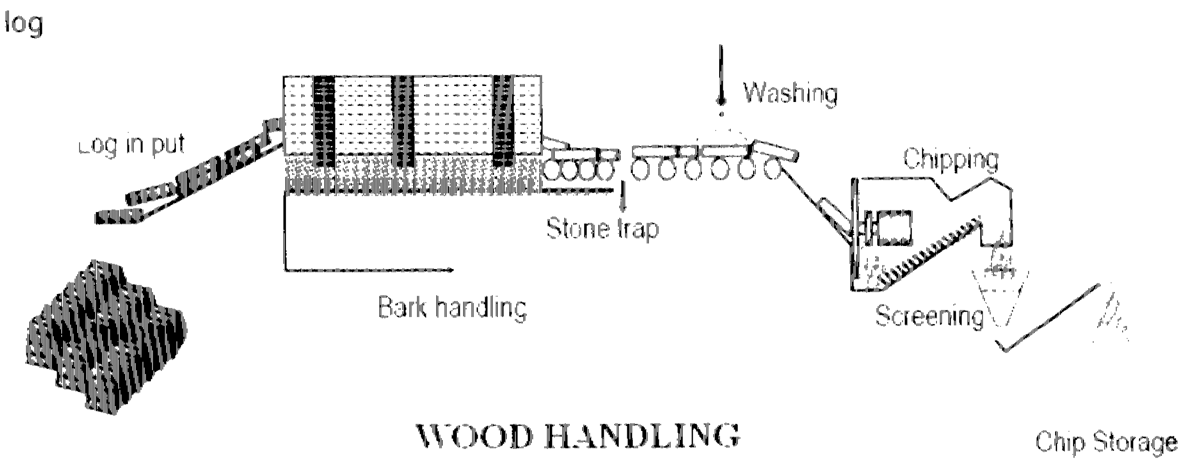


Figure 2.2: Mechanical pulping process flow

2.1.2 Chemical Pulping

The chemical pulping processes involve reaction or 'cooking' of wood chips with a solution of chemicals in a heated digester vessel for an extended period (up to several hours or more) followed by mechanical refining. There are two widely recognized processes for producing chemical pulp. One is known as sulfate pulping. The other is known as sulfite pulping. The major differences between these are the chemicals used, the quality of paper produced, and the economy of chemical recovery.

Sulfate pulping is a process that was developed in Germany in 1879. It is sometimes called kraft pulping because kraft means strength in German, and the paper produced with this chemical pulp is strong. It involves the use of caustic sodium hydroxide and sodium sulfide to extract the lignin from the wood fiber in large pressure vessels called digesters. The Kraft process is used for about 80% of production volume of paper. The pulp is usually darker than sulfite pulping, but it can be bleached to make very white pulp. Fully bleached kraft pulp is used to make high quality paper where strength, whiteness and resistance to yellowing are important. It can be used to make paper bags, writing paper, or diapers. Chemicals are typically always recovered in this process.

Sulfite pulping is a process that was developed in the United States in 1867. It produces wood pulp which is almost pure cellulose fibers by using various salts of sulfurous acid to extract the lignin from wood chips in digester. Sulfite pulping is carried out between pH 1.5 and 5, depending on the counterion to sulfite (bisulfite) and the ratio of base to sulfurous acid. The pulp is in contact with the pulping chemicals for 4 to 14 hours and at temperatures ranging from 130 to 160 °C. It generally results in a light chemical pulp that is easier to bleach and easier to refine. This process is acidic and one of the drawbacks is that the acidic conditions hydrolyze some of the cellulose, which means that sulfite pulp fibers are not as strong as kraft pulp fibers. Paper produced by this method can be used for newspaper, writing paper, or cellophane. With this method, however, there is not always chemical recovery.

Both processes are generally executed in a similar manner. Chemical pulping usually begins with debarking trees to create wood chips. Those chips are then cooked in a chemical mixture, or liquor. The purpose of this is to dissolve the wood's lignin, a natural component that binds the fibers together, and to break down other elements in the wood. When this part of the process is complete the liquor is generally black. This black liquor is what is used in the chemical recovery process. It can be used in the production of another chemical, such as tall oil. It can also be combusted to create heat or electrical energy. Chemical pulping generally results in the production of paper with greater sheet strength than the paper produced by mechanical pulping. It is also a process that can be regarded as highly efficient due to the possibility of chemical recovery.

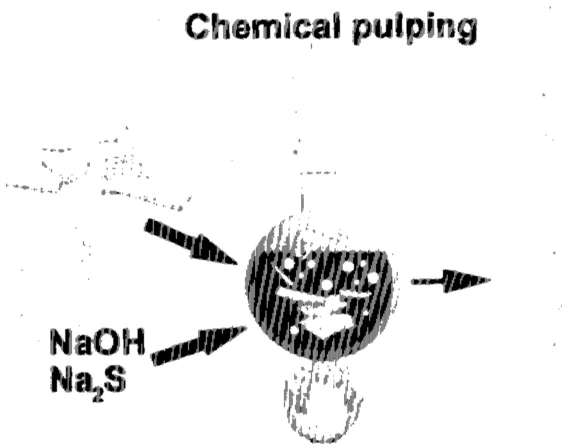


Figure 2.3: Chemical Pulping Process Flow

2.2 Paper Recycling

Recycling is the process of turning used products into raw materials that can be used to make new products. Its purpose is to conserve natural resources and reduce pollution. Recycling reduces energy consumption, since it generally takes less energy to recycle a product than to make a new one. Similarly, recycling causes less pollution than manufacturing a new product, and conserves raw materials. It also decreases the amount of waste sent to landfills or incinerators. Although people have always reused things, recycling as we know it today emerged as part of the modern environmental movement.

Paper is an example of a valuable material that can be recycled. The raw material of paper making is wood pulp, which comprises vegetable, mineral and manmade fibers. Most waste paper has to be sorted, graded and baled before going to the paper mills, and over 50 grades of waste paper have been identified. The quality of the waste determines the end quality of the recycled paper. Mixing all these different type of quality paper will reduce the purity of the highest quality fiber.

Most of the products made of paper only have a life span of a few days (e.g. newspapers) or a few weeks (e.g. packaging). Therefore, it is not striking that the thought of recycling has been a firm component of paper production for a long time. Most recovered paper is recycled back into paper and paperboard products. With a few exceptions, recovered paper is generally recycled into a grade similar to, or of lower quality than, the grade of the original product. For example, old corrugated boxes are used to make new recycled corrugated boxes. Recovered printing and writing paper can be used to make new recycled copy paper. Recovered paper contains some fibers which have become too small to be recycled into paper. However, this project will investigate the use of fiber in recycling paper and the enhancement to the new material properties compare to the original one.

The environmental benefits of paper recycling are many. Paper recycling has the abilities to:

- Reduces greenhouse gas emissions that can contribute to climate change by avoiding methane emissions and reducing energy required for a number of paper products.
- Extends the fiber supply and contributes to carbon sequestration which is the uptake and storage of atmospheric carbon.
- Saves considerable landfill space.
- Reduces energy and water consumption.
- Decreases the need for disposal (i.e., landfill or incineration which decreases the amount of CO_2 produced).

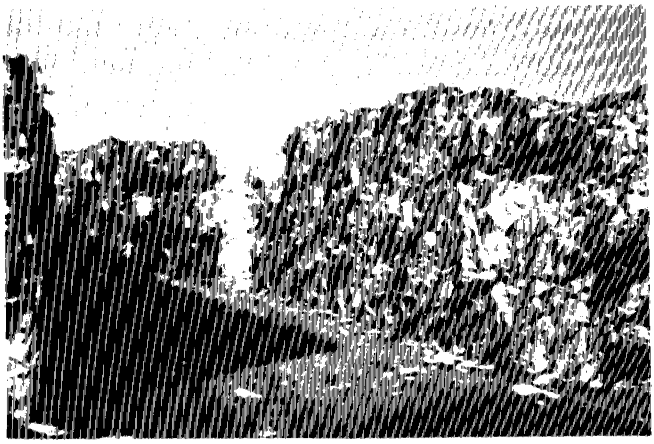


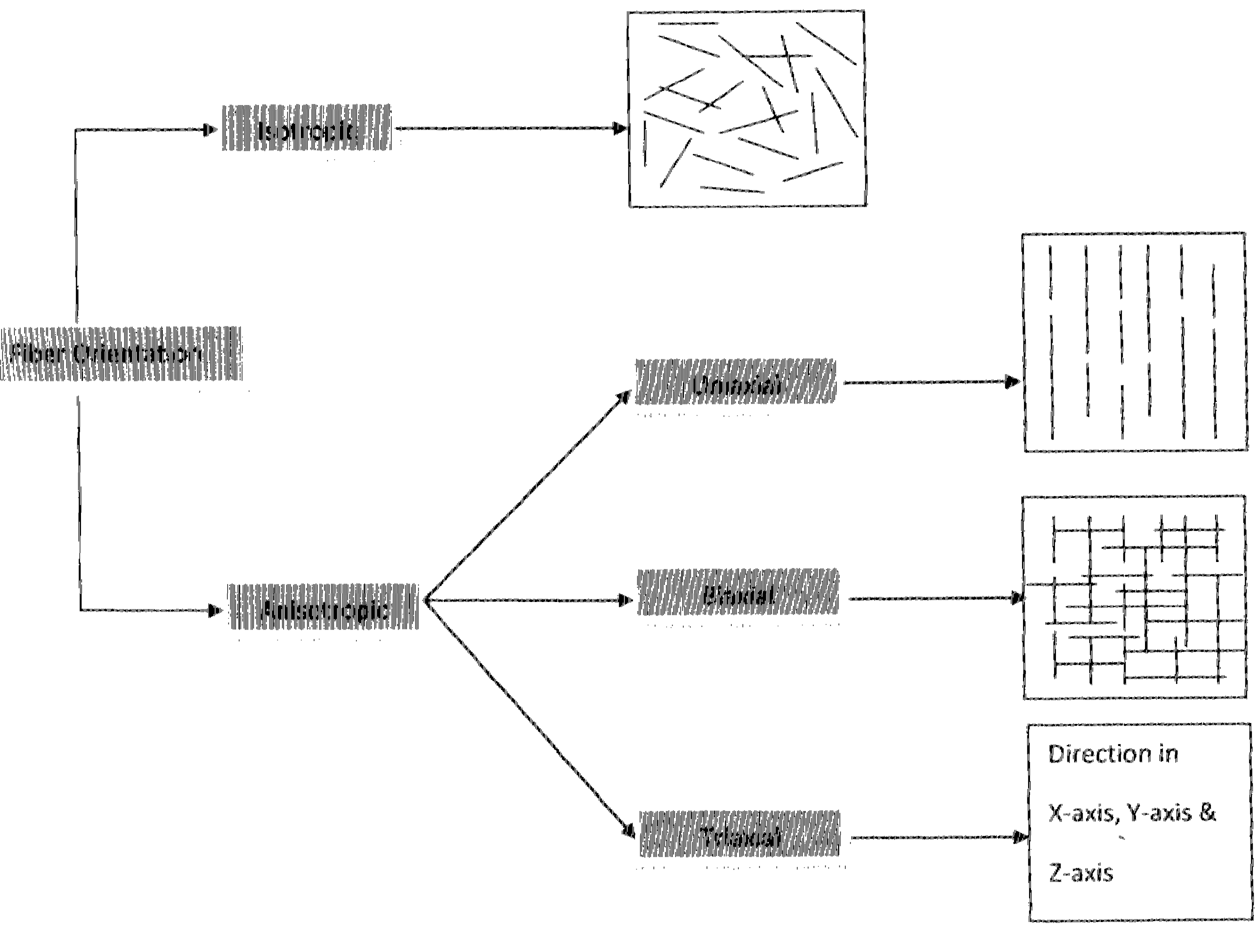
Figure 2.4: Paper Waste

2.3 Fiber Reinforcement and Orientation

Fiber reinforcement is generally used to improve mechanical properties of a material. Natural fibers are prospective reinforcing materials and their uses until now have been more traditional than technical. The advantages of these natural resources are low weight, low cost, low density, high toughness, acceptable specific strength, enhanced energy recovery and recyclability. For this project, oil palm fiber is selected as the suitable fiber that will act as reinforcement to the structure of the cellulose-based acoustic wall board. The reason is because oil palm fiber is very light and can absorb a lot of water without congealing. It can withstand extremes temperature and moisture conditions during food processing. Moreover, it is clean and toxic free.

Fiber orientation plays a strong factor in enhancing the strength of a material. Isotropic and anisotropic are the example of common orientation for material. Isotropy is identical in all directions and invariant with respect to direction. For anisotropic, there are three orientations which are uniaxial, biaxial and triaxial. Below is the example of the fiber orientation:

Figure 2.5: Fiber orientation



CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The project starts with background research on the topic of fundamental study of the pulping and paper recycling. In conducting this project, the research is divided into 3 stages:

1) Preliminary research

   The information related to pulping process and paper recycling is collected from books, journals, internet and articles. The criteria of fibers also are obtained from the lecturers and fiber expert. All the information is compiled for future references.

2) Experimenting

   The project is continue with the process of recycling paper. In this stage, the fiber selected will be use as reinforcement to the new cellulosic material.

3) Mechanical Testing & Data Collection

   The material will undergo several tests to determine the new properties obtained from the combination of pulp and fiber. The result and data are collected and compiled.

3.2 Flow Chart

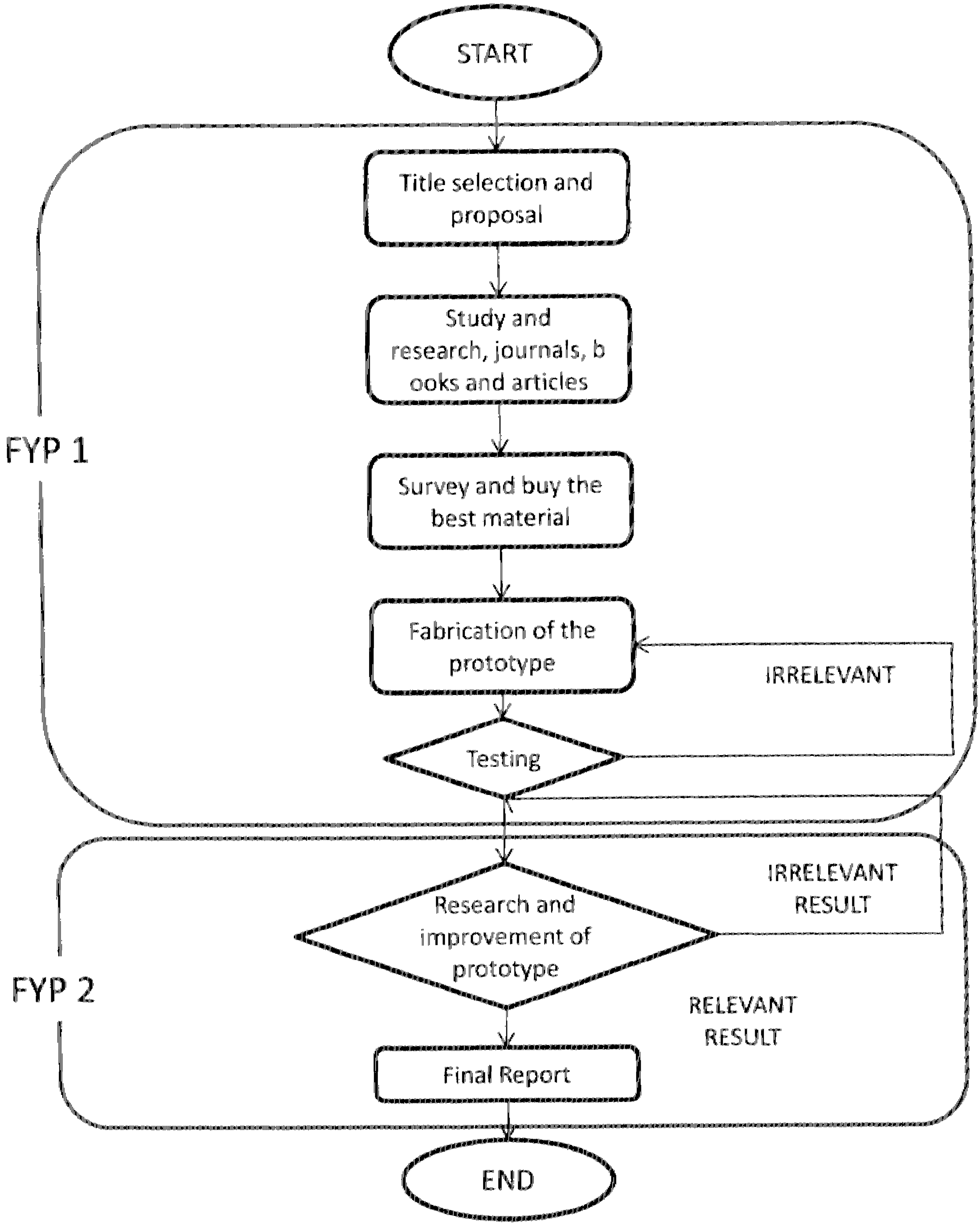


Figure 3.1: Project flow chart

3.3 Project Scheduling

In the Gantt Charts shown in Table 3.1 and 3.2, all activities are planned thoroughly.

Table 3.1: Gantt chart for Final Year Project I

No.	Detail/Week	Week	1	2	3	4	5	6	7			8	9	10	11	12	13	14	15
	Timelines for FYP 1	Status																	
1	Selection of Project Topic	DONE																	
2	Preliminary Research Work	DONE																	
2.1	Finding journal about pulping	DONE																	
2.2	Extract important fact	DONE																	
2.3	Discussion with Supervisor(SV)	DONE																	
3	Submission of Extended Proposal	DONE																	
3.1	Preparation for Proposal Defence	DONE																	
4	Proposal Defence	DONE																	
5	Project work continues	DONE																	
6	Submission of Interim Draft Report																■		
7	Submission of Interim Report																	■	

Table 3.2: Gantt chart for Final Year Project II

	Timelines for FYP 2																		
1	Project Work Continues																		
1.1	Prepare the pulping mold																		
1.2	Recycling process with fiber orientation(horizontal)																		
1.3	Recycling process with fiber orientation(vertical)																		
1.4	Recycling process with fiber orientation(random)																		
1.5	Experiment for determine the mechanical properties																		
2	Submission of Progress report											■							
3	Project Work Continues																		
3.1	Repeat the experiment (if needed)																		
4	Pre-EDX														■				
5	Submission of Draft Report															■			
6	Submission of Dissertation (soft bound)																■		
7	Submission of Technical Paper																■		
8	Oral Presentation																	■	
9	Submission of Project Dissertation (Hard Bound)																		■

3.4 Procedure

1. Prepare all the items to recycle paper manually. There are:
    - 2 identical picture frames. Get rid of the glass/acrylic sheet and only use the frame itself.
    - Mosquito net
    - Duct tape
    - Stapler
    - large tub that can fit both frames (one on top of the other) horizontally
    - Electric blender
    - Sponge
    - Paper
    - Natural Fiber (oil palm fiber) as reinforcement.
    - Blanket

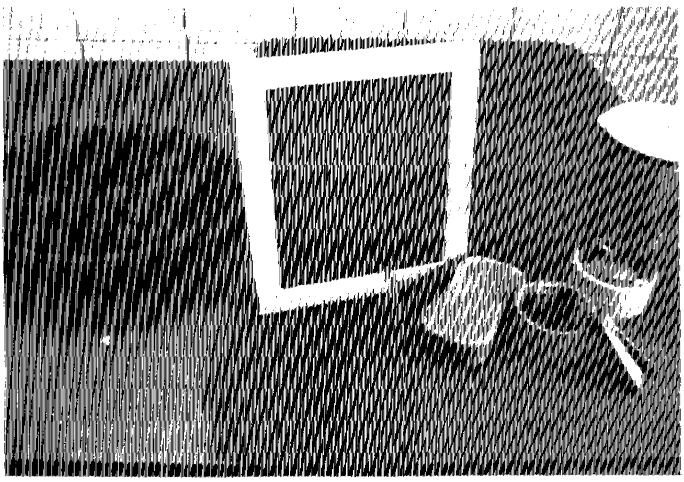


Figure 3.2: Item required

2. Prepare the "mold" by using one of the frame and the net. Cut the net according to the frame size and nailed it by using a stapler. Then sealed the side of the frame by using duct tape. The other frame remains unnetted, and is called the "deckle".

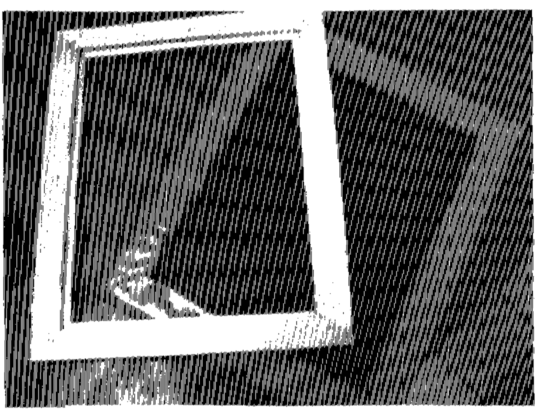


Figure 3.3: The Deckle and Mold

3. To produce the pulp, blend the paper until it totally shredded. Then pour the pulp into the tub. Repeat this process until both of the frames immersed in the pulp solution.

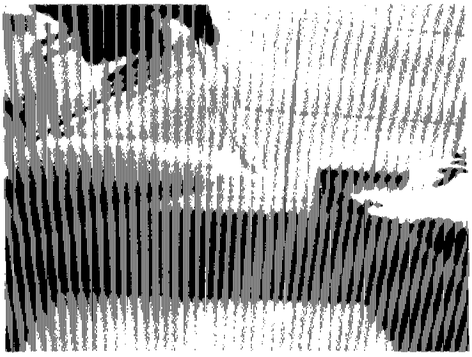


Figure 3.4: Pour the pulp into tub

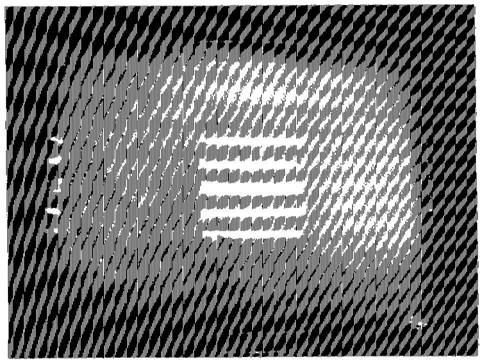


Figure 3.5: Pulp solution

4. Dip the frames in the tub and make sure that the mold goes at the bottom, with the netted side facing up, and the deckle goes on top of it, smooth side facing down. When the mixture in the water is evenly distributed, quickly lift up both frames. Let it drip for about 10 seconds and remove the deckle.

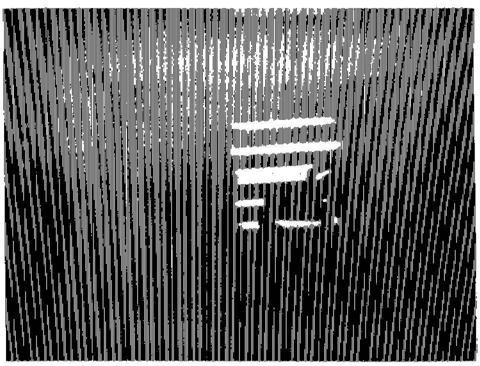


Figure 3.6: Dip both frames

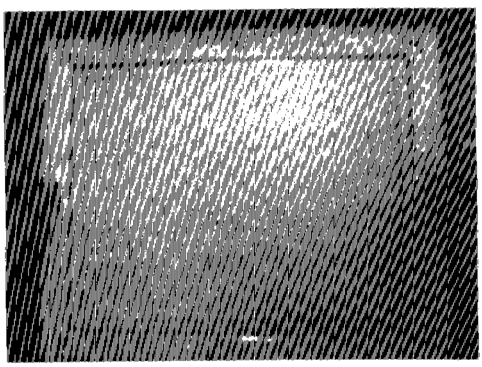


Figure 3.7: Lift both frames

5. Align one side of the mold (pulp facing the blanket) with the blanket and slowly lower the picture frame until it lays flat. Use a sponge and press it down on the net to suck up as much water as you can from the pulp. After that, slowly lift up the mold and it can be reused again.

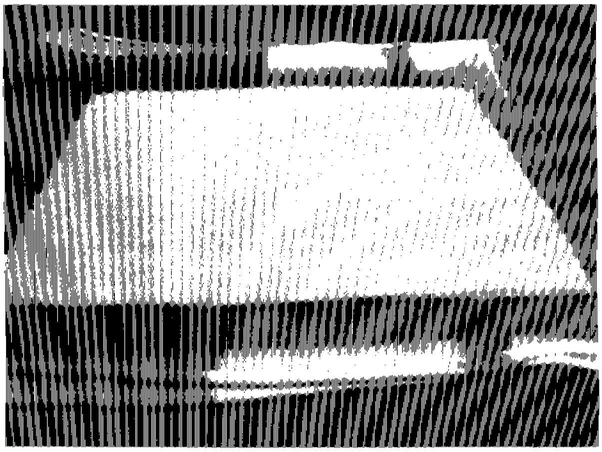


Figure 3.8: Lay onto the blanket

6. Take the fiber and arrange it on top of the first layer of the paper. In this project, the fiber will be arranged in isotropic and anisotropic orientation.

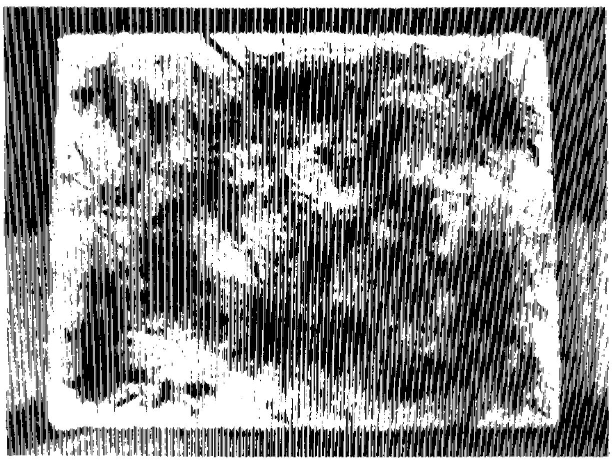


Figure 3.9: Fiber orientation (isotropic)

7. Repeat step 1-6 and stacked the paper on top of one another until it reached 5 layers. Then dry it under the sun for one whole day. After that, continue the procedure with anisotropic orientation.

3.4 Project Activities

Based on Table 3.3, the experimental work should start as early of week 1 based on UTP September academic semester. However, due to difficulties to get oil palm fiber, the work was shifted to week 4. Besides that, some of the redundant lab session with another student caused the schedule to be changed. Nevertheless, all of the experimental works are still conducted within the proposed time frame.

Activities	Starting Week	Finishing Week
Perform treatment to the fiber using hot water and dry it in the oven	Week 4	Week 5
Create the first cellulosic-based acoustic wallboard without fiber reinforcement	Week 5	Week 6
Create cellulosic-based acoustic wallboard with isotropic fiber orientation	Week 6	Week 7
Create cellulosic-based acoustic wallboard with anisotropic's uniaxial orientation	Week 8	Week 9
Create cellulosic-based acoustic wallboard with anisotropic's biaxial orientation	Week 9	Week 10
Laboratory testing and preparation for final report	Week 10	Week 12
Report Documentation	Week 12	Week 14

Table 3.3: Project Activities

3.3 Tools/Equipment

1. Blender
   A blender is used to shred the paper and turn it into slurry solution or pulp.

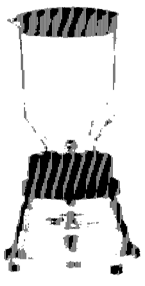


Figure 3.10: Electric Blender

2. Picture Frame
   Act as a mold and deckle to shape the pulp out from the blender.

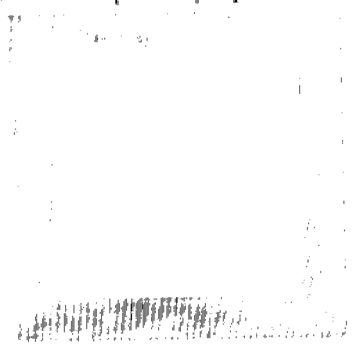


Figure 3.11: Picture Frame

3. Nylon Netting
   Combine with the picture frame to drain the pulp from the slurry solution

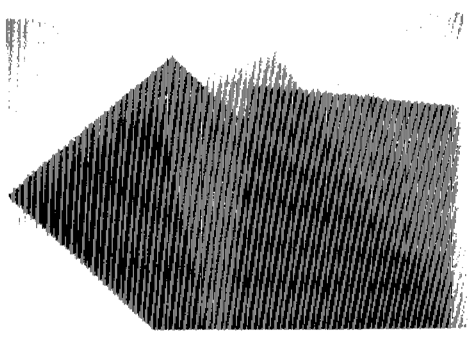


Figure 3.12: Nylon Netting

3.3 Tools/Equipment

1. **Universal Tensile Tester**

   Also known as a universal testing machine is used to test the tensile stress and compressive strength of materials. The specimen is placed in the machine between grips can automatically record the change in gauge length during the test

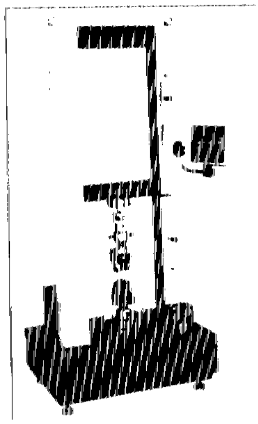


Figure 3.13: Universal Tensile Tester

2. **Audiometer**

   An audiometer is an instrument used to measure how well a person hears. It consists of an embedded hardware unit connected to a pair of headphones and a test subject feedback button, sometimes controlled by a standard computer. It consists of four parts, the oscillator, an audio amplifier, an attenuator and a pair of headphones.

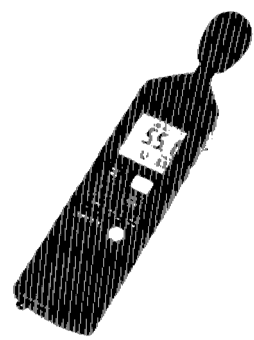


Figure 3.14: Audiometer

3. **Signal Generator**

A signal generator or also known as a test signal generator is an electronic device that generates repeating electronic signals (in either the analog or digital domains). They are generally used in designing, testing, troubleshooting, and repairing RF electronic devices. The output frequency can be tuned anywhere over their entire frequency range. In addition, many models offer various types of analog modulation, either as standard equipment or as an optional capability to the base unit.

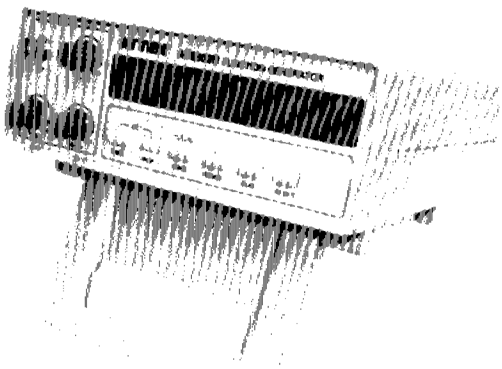


Figure 3.15: Signal Generator

CHAPTER 4

4.1 RESULT

In this project, the main goals are to create the wallboard from the combination of the paper waste and fiber reinforcement and to test the ability of the wallboard towards sound reflection and also the strength. There are four different types of wallboard created according to specific material orientation:

- Cellulose-based acoustic wallboard **without** fiber reinforcement

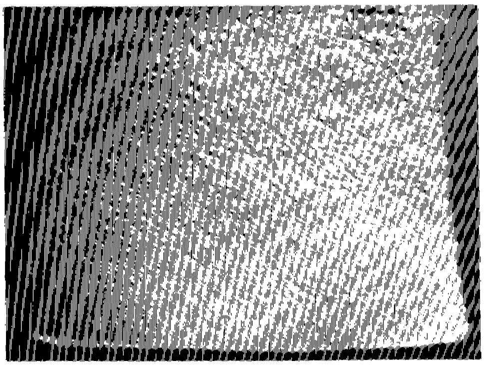


Figure 4.1: Wallboard without fiber

The wallboard undergoes the basic manual recycling paper process but it was stacked on one another for five layers. The surface is flat and clean.

- Cellulose-based acoustic wallboard with **Isotropic** fiber orientation

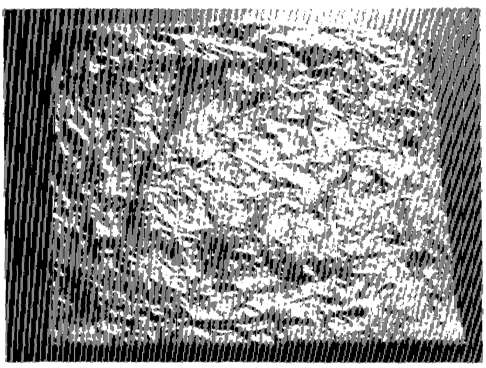


Figure 4.2: Wallboard with isotropic orientation

The fiber is placed randomly in each layer of the paper. The surface is rough and a little bit brownish due to the color discharge from the fiber.

1) **Sound Reflection Test**

The equipments for this test are set up like figure below. A channel is equipped on both of the speaker and microphone to allow the sound waves travel and focus to the wallboard. Both of them are placed according to the 45 degree angle to get the maximum sound reflection. Different frequencies are tested against fixed input amplitude to observe how strong the sound wave that have been reflected towards the wallboard. After the result is obtained, different wallboard will be changed and tested.

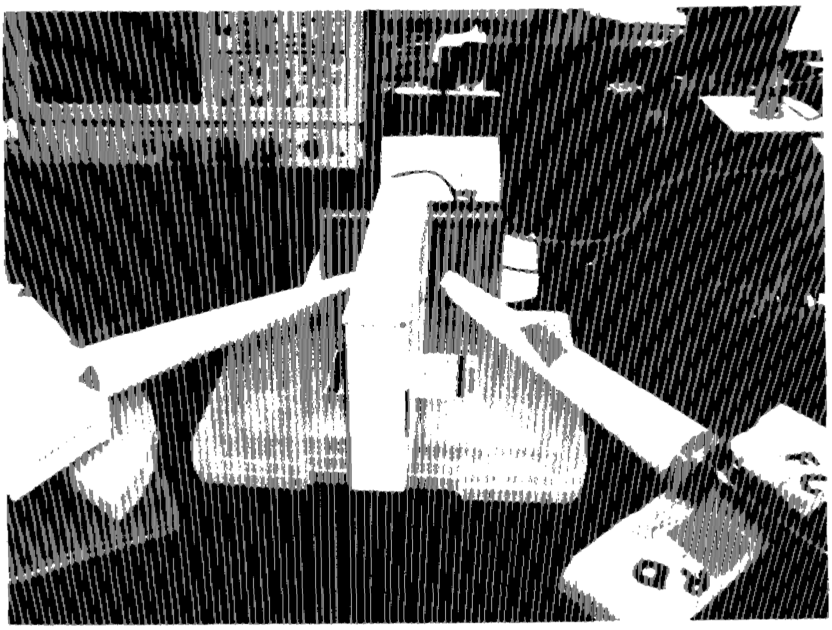


Figure 4.5: Equipments for Sound Reflection Test

- Wood wallboard

Input Frequency, f_i (Hz)	Input Amplitude, A_i (V)	Reflected Amplitude, A_o (V)
200	1.0	0.124
400	1.0	0.116
600	1.0	0.108
800	1.0	0.112
1000	1.0	0.124
1200	1.0	0.132
1400	1.0	0.180
1600	1.0	0.224
1800	1.0	0.248
2000	1.0	0.320
2200	1.0	0.332
2400	1.0	0.348
2600	1.0	0.361
2800	1.0	0.376
3000	1.0	0.445
3200	1.0	0.472
3400	1.0	0.504
3600	1.0	0.535
3800	1.0	0.592
4000	1.0	0.628

Table 4.1: Sound reflection test result for wood wallboard

- Wallboard without fiber

Input Frequency, f_i (Hz)	Input Amplitude, A_i (V)	Reflected Amplitude, A_o (V)
200	1.0	0.130
400	1.0	0.120
600	1.0	0.118
800	1.0	0.140
1000	1.0	0.160
1200	1.0	0.164
1400	1.0	0.176
1600	1.0	0.216
1800	1.0	0.232
2000	1.0	0.265
2200	1.0	0.284
2400	1.0	0.306
2600	1.0	0.318
2800	1.0	0.333
3000	1.0	0.357
3200	1.0	0.371
3400	1.0	0.388
3600	1.0	0.395
3800	1.0	0.416
4000	1.0	0.434

Table 4.2: Sound reflection test result for wallboard without fiber

- Wallboard with isotropy fiber orientation

Input Frequency, f_i (Hz)	Input Amplitude, A_i (V)	Reflected Amplitude, A_o (V)
200	1.0	0.128
400	1.0	0.124
600	1.0	0.115
800	1.0	0.136
1000	1.0	0.152
1200	1.0	0.161
1400	1.0	0.179
1600	1.0	0.220
1800	1.0	0.233
2000	1.0	0.258
2200	1.0	0.275
2400	1.0	0.292
2600	1.0	0.311
2800	1.0	0.323
3000	1.0	0.345
3200	1.0	0.360
3400	1.0	0.373
3600	1.0	0.388
3800	1.0	0.405
4000	1.0	0.421

Table 4.3: Sound reflection test result for wallboard with isotropy orientation

- Wallboard with uniaxial fiber orientation

Input Frequency, f_i (Hz)	Input Amplitude, A_i (V)	Reflected Amplitude, A_o (V)
200	1.0	0.127
400	1.0	0.125
600	1.0	0.118
800	1.0	0.139
1000	1.0	0.148
1200	1.0	0.157
1400	1.0	0.169
1600	1.0	0.182
1800	1.0	0.222
2000	1.0	0.248
2200	1.0	0.266
2400	1.0	0.282
2600	1.0	0.305
2800	1.0	0.311
3000	1.0	0.335
3200	1.0	0.350
3400	1.0	0.371
3600	1.0	0.382
3800	1.0	0.400
4000	1.0	0.418

Table 4.4: Sound reflection test result for wallboard with uniaxial orientation

- Wallboard with biaxial fiber orientation

Input Frequency, f_i (Hz)	Input Amplitude, A_i (V)	Reflected Amplitude, A_o (V)
200	1.0	0.130
400	1.0	0.126
600	1.0	0.119
800	1.0	0.140
1000	1.0	0.153
1200	1.0	0.166
1400	1.0	0.184
1600	1.0	0.210
1800	1.0	0.228
2000	1.0	0.247
2200	1.0	0.262
2400	1.0	0.284
2600	1.0	0.301
2800	1.0	0.319
3000	1.0	0.332
3200	1.0	0.358
3400	1.0	0.371
3600	1.0	0.383
3800	1.0	0.409
4000	1.0	0.417

Table 4.5: Sound reflection test result for wallboard with biaxial orientation

2) **Tensile Test**

The ability to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in structural applications. The force per unit area (MPa or psi) required to break a material in such a manner is the ultimate tensile strength (UTS). The rate at which a sample is pulled apart in the test can range from 0.2 to 20 inches per minute and will influence the results. The UTS is usually found by performing a tensile test and recording the stress versus strain the highest point of the stress-strain curve is the UTS. It is an intensive property, therefore its value does not depend on the size of the test specimen. However, it is dependent on other factors, such as the preparation of the specimen, the presence or otherwise of surface defects, and the temperature of the test environment and material.

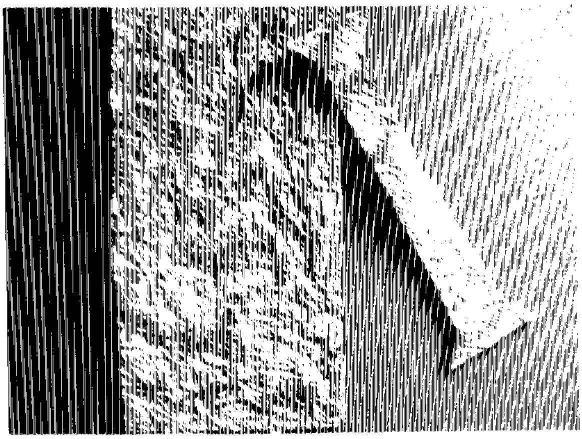


Figure 4.6: 'dogbone' shape

Material	Ultimate Strength (MPa)	Tensile Strength Increment percentage (%)
CB wallboard without fiber	10	-
CB wallboard with isotropy fiber orientation	14	20
CB wallboard with uniaxial fiber orientation	18	40
CB wallboard with biaxial fiber orientation	20	50

*CB – Cellulose-based

Table 4.6: Cellulose-based wallboard ultimate tensile strength

4.2 Discussion & Recommendations

The concept of sound reflection test is almost similar with light reflection. The speaker and the microphone distance and angle should be the same. As from the figure below, the desired angle is 45 degree and the optimum distance is about 50 mm from the wallboard. The sound wave that generated from the signal generator must be channeled and focused through the wallboard to avoid it from disperse into the surrounding.

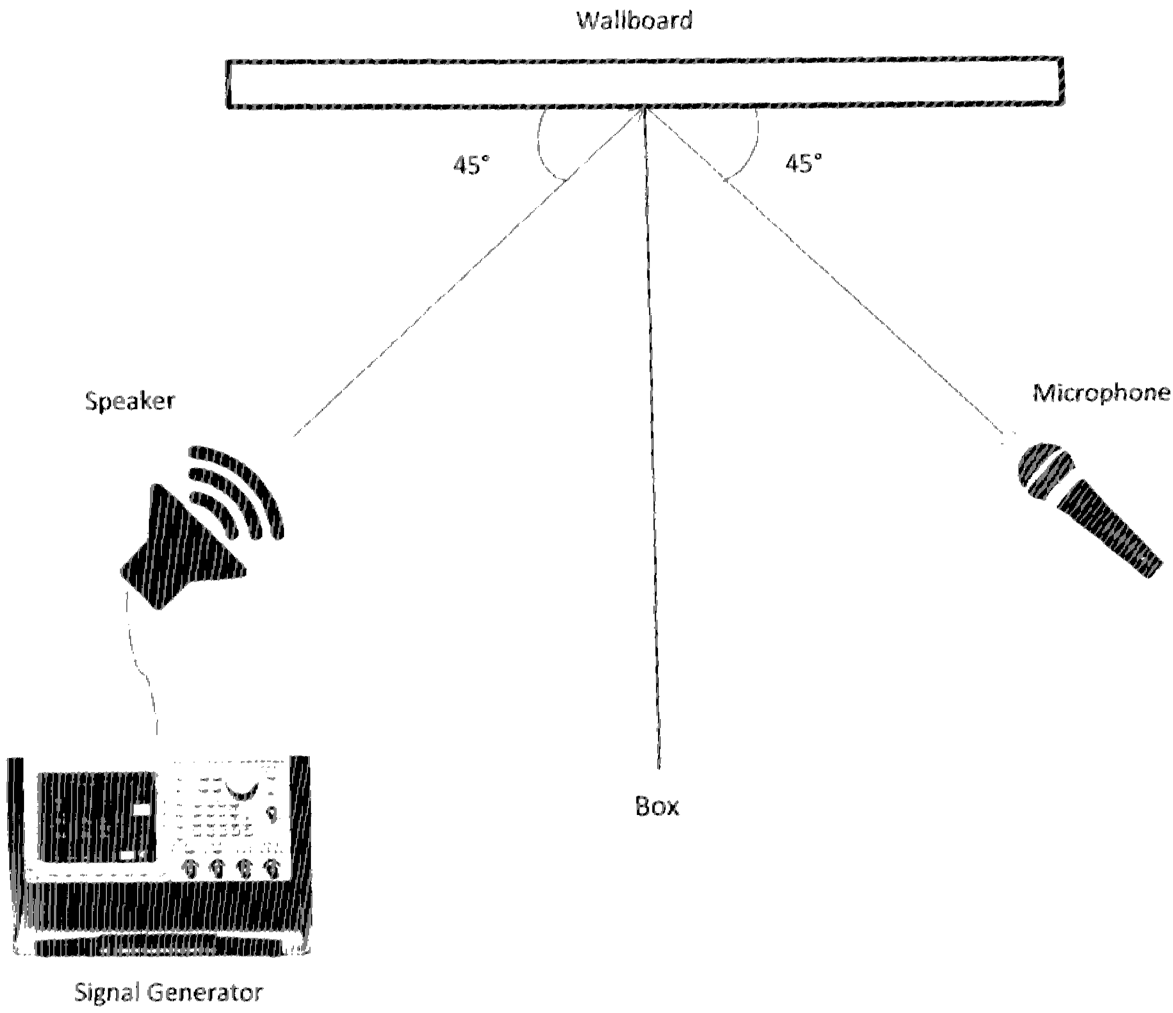


Figure 4.7: Sound reflection test

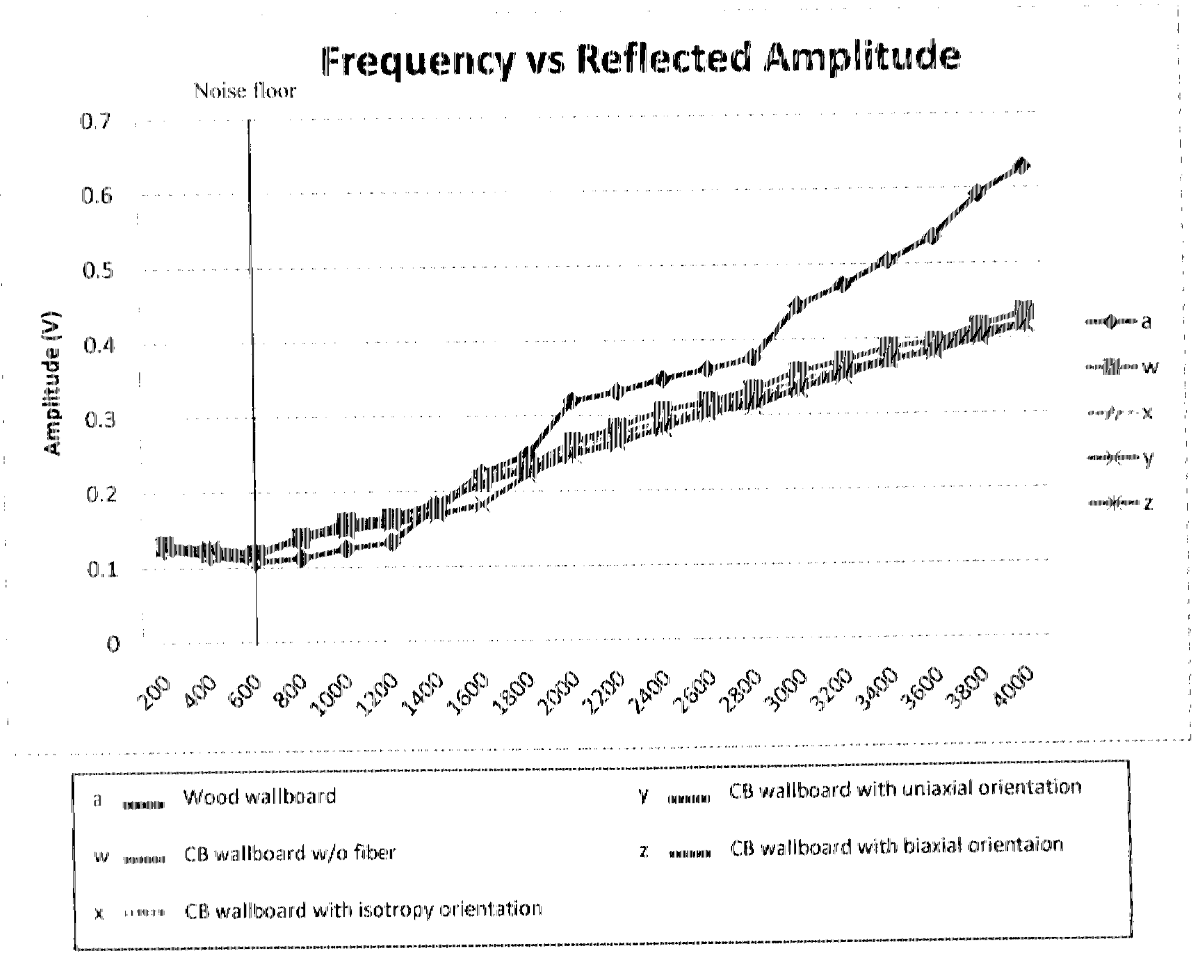


Figure 4.8: Frequency vs Reflected Amplitude graph

From the graph above, it is showed that all the cellulose-based acoustic wallboard created can reduce the sound reflection. The reduction in sound reflection started when the sound exceed the noise floor which is in this test is 600 Hz. After that, all the experimented wallboard shows a significant increment consistent with the frequencies. The wood wallboard stated the highest reflected amplitude when the frequency is increase until 4 KHz. The wallboard with anisotropy fiber orientation which are the uniaxial and biaxial are the greatest sound reflector material compare to others. This is because the uniform structure of the material and fiber create a good surface finish and flat surface that contributes to reduce the sound reflection.

Sound reflections can cause various problems such as phase, frequency response irregularity, loss of definition, aggressive highs, blurred image and low frequencies that are resonant, have holes in them and lack tightness. In performing the sound reflection experiment, there are several constraint and condition that can improve the result of the test. There are:

1) The experiment should be done in an acoustic room or surrounding in order to gain more accurate and precise result.
2) The shape of the room also can affect the sound reflection emitted by the speaker.
3) The experiment only considers normal noise level. Bass sound and high frequency sound wave (<20 KHz) are not included.
4) The sound emitted from the signal generator is neglected.
5) The use of sound absorber at the back of the wallboard can reduce the sound reflection.

The last experiment is the tensile strength test. All the wallboard will be cut into 'dogbone' shape (Figure 3.21). Both end of the specimen will be clamped and the force is applied until it breaks.

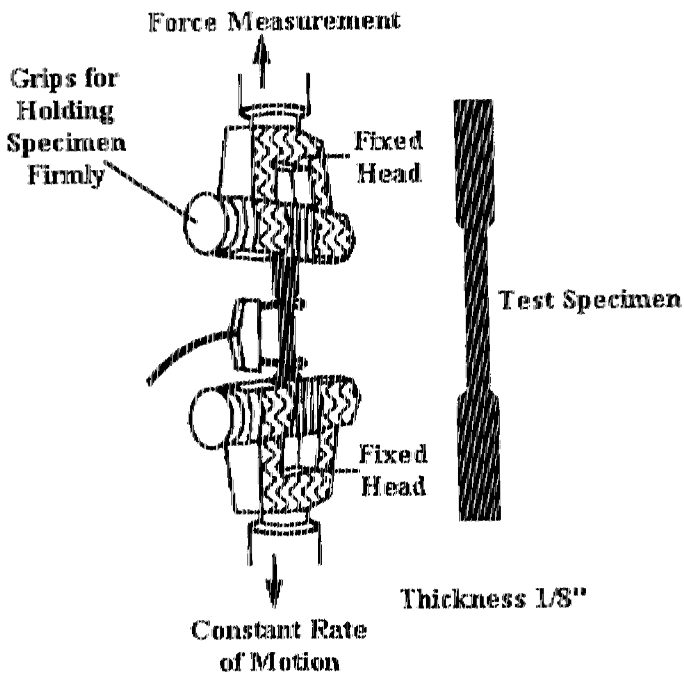


Figure 4.9: Tensile strength test simulation

Material	Wallboard without fiber	Wallboard with isotropy	Wallboard with uniaxial	Wallboard with biaxial
Original Length (mm)	200	200	200	200
Length after fracture(mm)	205	207	210	211
Percentage Elongation (%)	2.5	3.5	5.0	5.5
Original Cross Sectional Area (mm^2)	28.6	28.6	28.6	28.6
Cross Sectional Area after fracture (mm^2)	13.0	13.4	13.7	13.9
Percentage Reduction in Area (%)	54.5	53.1	52.1	51.4

Table 4.7: Cellulose-based wallboard elongation & area reduction

Table 4.7 shows that after the experiment the wallboard without fiber had elongated 2.5% and the cross sectional area at the point of fracture had decrease by 54.4%. The wallboard with isotropy fiber orientation elongated 3.5% and the cross sectional area at the point of fracture decreased by 53.1. Then the wallboard with uniaxial fiber orientation had elongated 5.0% and reduction in cross sectional area is 52.1% and lastly the wallboard with biaxial fiber orientation elongated 5.5% and the cross sectional area at the point of fracture decreased by 51.4%. It also shows that the wallboard with biaxial fiber orientation experienced more plastic deformation than other wallboard, and this is reflected by the higher percentage of elongation. After it had fractured, the surface of the wallboards was rough and irregular. The wallboard without fiber had a larger necking region that other wallboards sample, which explain the greater reduction in cross sectional area at the point of fracture. The wallboard without fiber sample showed a very rapid transition between the decreased area and the rest of its length whereas both wallboard with uniaxial and biaxial fiber orientation a gradually transition.

4.3 Conclusion

As for conclusion, creating the cellulose-based acoustic wallboard with different fiber orientation show an expected result for an acoustic wallboard. The addition of fiber with various orientation contribute to enhance the strength especially wallboard with biaxial fiber orientation. When sound is reflected, it can add a fullness, or spaciousness. The bad part of reflected sound occurs when the reflections amplify some notes, while cancelling out others, making the sound distorted. It can also affect tonal quality and create an echo-like effect. Moreover, lateral reflections create phantom sources outside the speakers, enlarging the stereo image. By doing so, they also contribute to enlarge every sound element distributed between the speakers. The result is a blurred image that lacks precision. To get the best and optimum acoustic effect, we must consider not only the wallboard material but also many other factors. The use of sound absorber and bass trapper can contribute in enhancing the sound quality in a space. The cellulose-based acoustic wallboards had been tested and prove that all of them can reduce the sound reflection compare to other common material. Furthermore, the cost for preparing is very cheap compare to egg tray and many others. Plus, the procedure to create it is easy and environmental friendly. By converting paper waste into something useful and new, the percentage of world's waste also can be reduce.

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